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2906 NW 14th Place
Gainesville, FL 32605

7 April 1998

Re: FCC ~~Docket~~ No. 97-297 and MM Docket No.97-182

Dear FCC:

Many species of songbird (warblers, vireos, thrushes, buntings, etc.) migrate at night. There is ample evidence that these migratory birds are killed by the thousands at tall, lighted towers. I have conducted some of this research myself, and there are dozens of other studies that have documented the phenomenon.

The migratory bird species affected are often the very same species already on the decline through various other factors. It is thus incumbent on regulatory agencies to take whatever available reasonable steps to reduce the risk to sensitive bird species. To that end, I urge you to support environmental review of the construction of new digital TV towers because the proliferation of these structures definitely poses a serious threat to migratory songbird populations.

Night-migrating birds congregate around tall, lighted towers because of the illumination. I strongly encourage cooperation among the FCC, the FAA, and the U. S. Fish and Wildlife Service to support research to develop lighting schemes that are safe for aircraft as well as for nocturnal migrants. The old style, red obstruction/warning lights that flash slowly or not at all are probably worse for birds than are newer, bright strobe lighting schemes, but there has been no research to verify this.

Reprints from some of my studies are provided for your information. Thank you for considering my comments.

Sincerely,

Michael L. Avery

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Wildlife Biologist

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The Composition and Seasonal Variation of Bird Losses at a Tall Tower in Southeastern North Dakota

Michael L. Avery, Paul F. Springer, and J. Frank Cassel

Introduction

NUMEROUS REPORTS OF BIRD MORTALITY at towers have been published in the past 20 years. The most extensive studies have been those of Stoddard and Norris (1967) and Crawford (1974) near Tallahassee, Florida, and Laskey (1956 – 1969b) and her associates in Nashville, Tennessee. Although the mass mortality of birds at towers is regrettable, it does provide investigators with much otherwise unobtainable information concerning nocturnal migration. Tordoff and Mengel (1956) were the first to make extensive use of this source of data to obtain information on sex, age, weight, molt, and other characteristics of the migrants. Until means are developed to prevent bird losses at towers, it is urged that greater use be made of this otherwise wasted source of study material.

The 366-m transmitting tower of the U.S. Coast Guard's Omega Navigation Station in southeastern North Dakota was completed in September 1971. Because of concern by some conservationists over the possible effects of this structure on birds, particularly waterfowl, migrating through the James River Valley, a study was conducted from September 1971 through November 1973 to record and evaluate the extent of losses and seasonal variation in the composition of the kill at the Omega tower.

Methods

Description of Tower Site

THE OMEGA NAVIGATION STATION is about 1.5 km west of the James River and 3.0 km west of LaMoure. The tower is situated in a marshy area that includes some grassy upland. A complete description of the site and the tower has been published elsewhere (Avery *et al.* 1976, 1977).

Sampling Plan

SINCE THE MARSHY NATURE of much of the habitat made it impossible to effectively search the entire area (168 ha) under the extensive transmitting cables and guy wires for dead birds, a sampling plan was devised (Fig. 1). The plan was based in part upon findings of previous studies of mortality at towers which indicated that most dead birds are found within about 60 m of the central structure. Thus, the intensity of the sampling was greatest near the tower. The inner gravel area within 46 m of the tower was examined completely for birds. The three service roads were also included in this stratum (A) because it was felt that these roads, lying under the three sets of supporting guy wires, might receive a disproportionately greater number of dead birds than areas between the sets of guys.

Other strata (B, C, and D) were formed by concentric circles with radii of 92 m, 183 m, and 732 m, respectively. Two compass lines, one running north-south and the other east-west, divided these strata into 12 substrata beyond the central area. Two square sampling plots, 12.4 m on a side, were randomly located in each substratum. The 19 sampling plots in wet sites consisted of nylon netting suspended by steel frames 1.5 m high. The center of each net was anchored to the ground, and a wooden railing around the top at the perimeter of each net prevented birds from being blown out. The remaining five sampling plots were gravel surfaces on upland sites.

This initial sampling system was subsequently modified in spring 1972 when it was determined that the sampling intensity in the outermost stratum was not great enough to estimate accurately the kill in that stratum. Consequently, the entrance road beyond 183m was incorporated into the sampling plan in the outermost stratum. Although the road was not located randomly within the stratum, it did not lie directly beneath any of the transmitting cables or guy wires and, therefore, except for possible effects of prevailing winds, it was situated randomly with respect to the falling of dead birds. This modification increased the sampling area from 0.07 to 0.60 per cent in the stratum.

Searches for Dead and Injured Birds

Except for seven days, searches for tower casualties were made at dawn daily during four seasons: March 30 – June 4 and August 8 – November 15, 1972, and April 2 – June 2 and August 12 – November 3, 1973. In addition, searches were made on several days before and after each period of daily searches. Birds not found on sampling areas are included in the overall species list, but are not included in the projected kill estimates derived from the sampling plan (Table 1). In fall 1971, members of the staff of the Northern Prairie Wildlife Research Center conducted searches of the inner gravel area and roads two or three times weekly. These findings are included in Table 1, but no estimate of the total mortality for that season was possible because the sampling system was not in operation until spring 1972.

Removal of tower-killed birds by scavengers was assessed each season in 1972 and 1973 by placing tagged, dead birds on the inner gravel area, roads, and some of the 24 sampling sites. Usually, birds that were not taken overnight by scavengers were picked up in the morning during the search for tower casualties; however, some were left in place as long as 18 days before being removed by the investigator.

Surveys of Bird Inhabitants

In order to determine the species frequenting the area, records were kept on the number of live birds seen in the marsh and upland within a distance of approximately 10 m

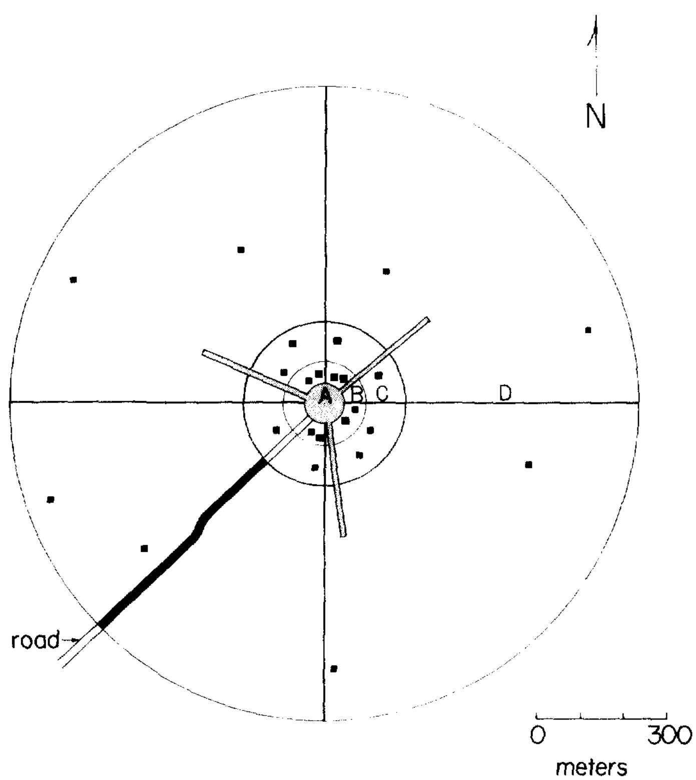

Figure 1 - Omega Navigation Station site showing sampling plan (road and sampling plots not drawn to scale)

on each side of the path of the investigator during his daily searches for tower casualties. In addition, surveys of birds were conducted at least three mornings weekly in the James River Valley along 40 km of roads north and east of the tower site. Habitats surveyed included a semipermanent marsh, a permanent lake, several agricultural fields and pastures, five shelterbelts, and a tract of wooded river bottomland. The surveys were made on foot in one shelterbelt and in the bottomland; the others were made from a car.

Statistical Methods

Seasonal variation in the composition of the losses was analyzed with chi-square tests of independence on the families and on the 26 most frequently killed species. Kendall's Tau (Conover 1971, Ghent 1972) was employed as a measure of rank correlation between the numbers of migrants seen in the field and the losses at the tower in 1972 and 1973. Due to space limitations the tabulation of the statistical test results could not be included fully in this paper, but they are available from the authors upon request.

Nomenclature

Common names of birds correspond with those in the A.O.U. Check-List, 5th edition and supplements.

Results and Discussion

Extent of Losses

FROM SEPTEMBER 1971 through November 1973, 937 birds were found dead or injured at the Omega tower (Table 1). In addition, five Red Bats (*Lasiurus borealis*) were found dead, one in fall 1971 and four in fall 1972. The diversity in the composition of the losses — 102 species, 22 families, 10 orders — is notable in view of the relatively small number of individuals actually collected. The only other published data showing greater numbers of species are two long-term studies. Stoddard and Norris (1967) and Crawford (1974) made daily searches year-round at a TV tower near Tallahassee and collected about 35,000 individuals of 177 species during an 18-year period. Regular monitoring of two TV towers in Nashville produced over 17,000 birds of 110 species in 14 years (Ganier 1962, Laskey 1956-1969b).

Other studies reporting many more individuals but fewer species killed than at the Omega tower either did not include daily searches (e.g., Caldwell and Wallace 1966 — 6505 birds, 92 species) or included only spring or fall searches (e.g., Taylor and Anderson 1973 — 7782 birds, 82 species).

On the basis of the 484 birds found on sampling areas, the estimated kill for 1972 and 1973 averaged about 1075 birds per season (Table 1). The estimated seasonal losses remained fairly constant the first two seasons, but varied more thereafter. The contribution to the total estimated kill from Stratum D (183-732 m from the tower) was considerable in each season and suggests that at the Omega tower, most mortality was caused by guy wires and transmitting cables far from the central structure. The estimated mortality must be viewed with caution because the sampling intensity in Stratum D was very low. More intensive sampling in this stratum would have made the estimates more reliable.

Scavengers and Predators

THE PRESENCE OF VARIOUS scavengers and predators was noted in the vicinity of the tower throughout the study. Raccoons (*Procyon lotor*) were the most common mammalian components, but Red Foxes (*Vulpes vulpes*), Striped Skunks (*Mephitis mephitis*), Mink (*Mustela vison*), and Badgers (*Taxidea taxus*) were also present. Avian members included Red-tailed Hawks, Marsh Hawks, Great Horned Owls, and Short-eared Owls.

To assess the impact of these scavengers and predators, a total of 296 test birds were placed out during the four seasons in 1972 and 1973. Test birds were not placed entirely at random; occasionally some were placed selectively where particularly active scavenging was suspected. Thus, losses of test birds during the first night varied with the season from 2.4 per cent in spring 1972 to 17.6 per cent in spring 1973, and averaged 7.4 per cent overall. Six of the nine test birds lost during the night in spring 1973 were taken from two gravel sampling plots in Stratum D near an active fox den. These birds were placed there specifically to test the possibility that the foxes were searching the two sampling plots regularly in their foraging activity. If these six birds are excluded, only 3 of 45 (6.7%) test birds were taken during the first night in spring 1973, and the overall average is reduced to 5.5 per cent. On the basis of these findings, we feel that daily searches kept the losses of tower-killed birds to scavengers and predators at a level that did not unduly affect the estimates of total mortality (Table 1).

The effectiveness of the 19 sampling nets in preventing losses to scavengers and predators was demonstrated by the fact that none of the 33 test birds placed in nets during the study were taken during the first night, whereas 12 of the 69 (17.4%) test birds placed on the five gravel sampling plots were taken during the same length of time.

The level of scavenging at the Omega tower was considerably less than that reported from the WCTV tower near Tallahassee (Crawford 1971) where only 10 per cent of the 157 test birds were left undisturbed after one night. Conceivably, tower-killed birds could form a substantial supplement to the diet of a scavenger or predator, especially at a site where mortality is of regular occurrence. Predator control measures may be deemed necessary in some instances if the collection of reliable data is to be assured (Crawford 1974). While it is not possible in many situations, daily monitoring of tower mortality is essential in order to keep the loss of specimens to scavengers and predators at a minimum. In addition, dead birds that are not collected soon after death deteriorate rapidly and are rendered useless in studies of fat content.

Table 1. Bird casualties and estimated mortality at the Omega tower, fall 1971 through fall 1973

Species	*Fall 1971*	*Spring 1972*	*Fall 1972*	*Spring 1973*	*Fall 1973*	*Total*
Eared Grebe			1			1
Western Grebe		2				2
Pied-billed Grebe		1		1	3	5
American Bittern			2	1		3
Mallard	1		1	2		4
Gadwall				1		1
Pintail		1	1			2
Blue-winged Teal	1		1		1	3
Northern Shoveler			1			1
Lesser Scaup		5	2			7
Ruddy Duck			1			1
Marsh Hawk			1			1
Virginia Rail		7	2	1	1	11
Sora	3	14	12	10	7	46
Yellow Rail			1			1
American Coot	1	8	13	1	3	26
Killdeer				1		1
Common Snipe			1	2		3
Pectoral Sandpiper				1		1
American Avocet				1		1
Northern Phalarope					1	1
Mourning Dove			1	1	1	3
Black-billed Cuckoo		1		1		2
Common Flicker				1	1	2
Eastern Kingbird				1	1	2
Yellow-bellied Flycatcher			1			1
Traill's Flycatcher	1		1	2	3	7
Least Flycatcher		1		2		3
Tree Swallow		1				1
Bank Swallow				1		1
Barn Swallow	1				1	2
Brown Creeper		1				1
House Wren	2	6	2	1	2	13
Long-billed Marsh Wren	2	11			1	14
Short-billed Marsh Wren	1	1			1	3
Gray Catbird		1		1	1	3
Brown Thrasher		2				2
Sage Thrasher				1		1
Hermit Thrush			1			1
Swainson's Thrush		4	4	5	2	15
Gray-cheeked Thrush		3	5	1		9
Veery		1	1			2
Golden-crowned Kinglet	1		3		4	8
Ruby-crowned Kinglet		2	3			5
Starling				2		2
Bell's Vireo		1				1
Solitary Vireo	2					2
Red-eyed Vireo	14	1	4	2	10	31
Philadelphia Vireo				1		1
Warbling Vireo	6	1	2	2	1	12
Black-and-white Warbler	1	1	3	1	1	7
Golden-winged Warbler			1			1
Tennessee Warbler	1	2	1	5	3	12
Orange-crowned Warbler	7		9	2	6	24
Yellow Warbler	15	1	19	4	21	60
Magnolia Warbler			1			1
Black-throated Blue Warbler					1	1
Yellow-rumped Warbler	2		13	1	4	20

Table 1 continued. Bird casualties and estimated mortality at the Omega tower, fall 1971 through fall 1973.

Species	*Fall 1971*	*Spring 1972*	*Fall 1972*	*Spring 1973*	*Fall 1973*	*Total*
Black-throated Green Warbler			1			1
Blackburnian Warbler	1				1	2
Bay-breasted Warbler			2			2
Blackpoll Warbler		2	2	1	3	8
Palm Warbler		3	9			12
Ovenbird	5	1	6		2	14
Northern Waterthrush	1	1	2	1	2	7
Mourning Warbler	15		6		5	26
Common Yellowthroat	3	16	8	5	5	37
Wilson's Warbler	10		4		6	20
Canada Warbler	3		1			4
American Redstart		2	2		1	5
Bobolink		3		1		4
Western Meadowlark		2		1	1	4
Yellow-headed Blackbird		7	1	2		10
Red-winged Blackbird	1	1	1	1		4
Orchard Oriole		1	1			2
Northern Oriole	2		1		3	6
Brown-headed Cowbird	1	4	2	1	2	10
Rose-breasted Grosbeak				1	1	2
Common Redpoll	1	2				3
Pine Siskin				1		1
Rufous-sided Towhee		1				1
Lark Bunting		2				2
Savannah Sparrow	8	22	10	6	8	54
Grasshopper Sparrow		21	3	3	1	28
Baird's Sparrow		2				2
Le Conte's Sparrow	2	16	3		3	24
Sharp-tailed Sparrow		1	1			2
Vesper Sparrow	1	3	2		3	9
Dark-eyed Junco		4	4	4	3	15
Tree Sparrow	5	8	7	3	5	28
Chipping Sparrow		4	1		2	7
Clay-colored Sparrow	2	20	7	2	26	57
Harris' Sparrow	4	2	3		3	12
White-crowned Sparrow		1			1	2
White-throated Sparrow	1	3	3	4	3	14
Fox Sparrow			1			1
Lincoln's Sparrow	6	4	4		12	26
Swamp Sparrow	1	1	3		3	8
Song Sparrow	1	4	2	1	1	9
Lapland Longspur	7	5	5	4	6	27
Smith's Longspur	1		1	1	1	4
Chestnut-collared Longspur					1	1
Unidentified	8	6	2	2	4	22
Total (102 species)	152	255	226	105	199	937
Number of birds found on sampling areas — Stratum A(1)[1]	—	131	142	54	110	437
B(16)	—	4	5	1	8	18
C(64)	—	1	5	3	3	12
D(165)	—	5	3	7	2	17
Estimated kill	—	1084	1037	1417	760	4298

[1] Expansion factor for each stratum is given in parentheses.

sex composition, etc. The use of nets such as those described herein, effectively discourages mammalian scavengers, but may be less effective against owls or other avian predators and scavengers.

Seasonal Variation in Kill

The composition of the kill varied considerably by season. Chi-square analysis showed that two families accounted for over half of the overall seasonal variation — warblers (44%) and vireos (11%). These birds were killed predominately in the fall. Wrens, icterids, and fringillids, all of which suffered greater spring than fall losses, each accounted for about 8 per cent of the total variation.

Table 2 shows that seasonal variation of losses was highly significant at the species level. Of the 26 most frequently killed species, mortality was proportionately higher for 6 in the spring and 8 in the fall. The remaining 12 species displayed no large seasonal differences in mortality, contributing less than 3.0 each to the overall x^2 value. Among the warblers and vireos, only the Common Yellowthroat incurred appreciably greater spring than fall losses, and among the fringillids, only the Lincoln's Sparrow suffered appreciably greater fall than spring losses.

The species in Table 2 that had proportionately greater spring than fall losses were observed commonly in the marsh and upland around the tower during the spring months and are common or locally common breeding birds in the southeastern part of the state (Stewart 1975). Stoddard

Table 2. Seasonal losses, by species, at the Omega tower.

Species[1]	Mortality Spring 2 seasons	Fall 3 seasons	Total	Contrib. to x^2
(S) Sora	24	22	46	3.46
(E) American Coot	9	17	26	0.16
(E) House Wren	7	6	13	1.29
(S) Long-b. Marsh Wren	11	3	14	9.51
(E) Swainson's Thrush	9	6	15	2.94
(F) Red-eyed Vireo	3	28	31	10.86
(E) Warbling Vireo	3	9	12	0.92
(E) Tennessee Warbler	7	5	12	2.00
(F) Orange-c. Warbler	2	22	24	9.21
(F) Yellow Warbler	5	55	60	23.02
(F) Yellow-rumped Warbler	1	19	20	9.47
(E) Palm Warbler	3	9	12	0.92
(F) Ovenbird	1	13	14	5.80
(F) Mourning Warbler	0	26	26	16.26
(S) Common Yellowthroat	21	16	37	5.23
(F) Wilson's Warbler	0	20	20	12.50
(S) Savannah Sparrow	28	26	54	4.09
(S) Grasshopper Sparrow	24	4	28	26.40
(S) Le Conte's Sparrow	16	8	24	8.06
(E) Dark-eyed Junco	8	7	15	1.40
(E) Tree Sparrow	11	17	28	0.01
(E) Clay-colored Sparrow	22	35	57	0.00
(E) Harris' Sparrow	2	10	12	2.41
(E) White-th. Sparrow	7	7	14	0.79
(F) Lincoln's Sparrow	4	22	26	5.85
(E) Lapland Longspur	9	18	27	0.30
	237	430	667	162.86
All other species	115	133	248	6.54
Total[2]	352	563	915	169.40

[1] (S) = greater spring losses, (F) = greater fall losses.
(E) = approximately equal spring and fall losses.
[2] Does not include 22 unidentified birds.

and Norris (1967:71) noticed a similar relationship in their study: ". . . a relatively large spring kill seems more likely to pertain to species that breed abundantly with us . . . than to ones that travel farther north to their breeding ground." It would be interesting to know if this same pattern occurs elsewhere, but no other detailed reports of spring mortality at towers are known to us.

We hypothesize that migrants of locally breeding species are more selective in the spring than in the fall as to where they alight following a night's migration. As they descend in the early hours of the morning, birds whose characteristic nesting habitat resembles the area around the Omega station encounter a greater concentration of guy wires near the tower and suffer greater mortality than do species that breed in other habitats and remain at higher altitudes, not attracted to the marsh and grassy upland surrounding the tower.

Some mortality at the Omega tower may occur at dawn or dusk during local flights by resident birds. Depending on the extent of such activity, it, too, might help account for the abundance of locally breeding species in the spring kill. Throughout the study, birds observed flying in daylight hours near the Omega station avoided the guy wires and tower. However, it is conceivable that during times of poor visibility in the breeding season, birds engaging in aerial chases or flight displays occasionally strike guy wires.

THE SPECIES THAT EXHIBITED greater fall mortality (Table 2) were rarely seen in the vicinity of the tower at any time, and most do not breed commonly in the southeastern portion of the state (Stewart 1975). Exceptions were the Red-eyed Vireo (locally common) and Yellow Warbler (common). Of those species not differing greatly in their seasonal losses, only the American Coot and Clay-colored Sparrow were observed regularly at the tower site. They were common in 1972 when suitable habitat existed for them, but were seen only infrequently in 1973 when water levels were lower and brushy areas used by the sparrows were destroyed by grazing cows.

Seasonal variation in the species composition of tower kills has been noted by others (e.g., Caldwell and Wallace 1966, Stoddard and Norris 1967). In

Michigan, Caldwell and Wallace found 24 species distributed unequally by season and suggested different spring and fall migration routes as a possible explanation. In our study, this possibility was examined by rank correlations between tower losses and field observations made during the migration seasons of 1972 and 1973. All passerine species seen in the field or killed at the tower were included in the analysis. Many nonpasserine species, particularly waterfowl and shorebirds, were seen by the hundreds in the field but appeared in the kill only rarely. Thus, all nonpasserines were excluded from this analysis because it was known *a priori* that no positive correlation existed.

There was a significant ($p<0.001$) correlation between total field observations and tower losses in the spring but not in the fall. When analyses were made on vireos and warblers combined, and on fringillids, significant ($p<0.005$) correlations were obtained in both spring and fall. These results indicate that the variations in the composition of the kill reflected corresponding seasonal differences in the local abundance of certain groups of passerine migrants. These differences may have been due to different spring and fall migration routes, as suggested by Caldwell and Wallace (1966).

Several exceptions to the relationship between field counts and tower kill were evident. The Yellow and Yellow-rumped Warblers were observed in the field more often in the spring but appeared much more often in the fall kill. Species such as the American Goldfinch and Chestnut-collared Longspur, which generally migrate diurnally, were very abundant in the field but were almost totally absent from the kill. Others, such as the Mourning Warbler and Grasshopper and Lincoln's Sparrows, which are difficult to observe in the field, appeared in the kill in greater relative numbers than they were observed during field surveys.

Previous investigators have reported on the relationship between tower kills and field observations of migrants. Graber (1968) found no correlation between fall field counts and tower kills when all species were considered; however, when comparisons were limited to closely related species (e.g., *Dendroica* warblers), correlations were significant. Weise (1971), using fall mist net data instead of field observations, reported similar results. Our findings are in agreement and indicate that tower kills do provide a reliable index of the relative abundance of certain species of migrants through a given area.

The cause of certain species suffering greater mortality at towers in one season or the other probably involves a combination of factors. In addition to those discussed here, other variables such as weather, different heights of migration in spring and fall (Bellrose and Graber 1963), and interspecific differences in the effects of tower lights on migrants must also be considered.

Summary

BEGINNING IN SEPTEMBER 1971, bird mortality was monitored during five seasons of migration at the 366-m transmitting tower of the U.S. Coast Guard's Omega Navigation Station, LaMoure, North Dakota. In summary, the findings were: (1) Throughout the study, 937 birds of 102 species were found dead or injured at the site. Based on a stratified random sampling system, the average estimated seasonal mortality in 1972 and 1973 was about 1075. (2) The composition of the losses varied seasonally — warblers and vireos dominating the fall kills and wrens, icterids and fringillids the spring kills. Birds displaying greater spring than fall losses were primarily species that breed abundantly in southeastern North Dakota. (3) Rank correlation analysis showed that the abundance in the field of vireos and warblers and of fringillids was correlated positively with their occurrence in the tower kill in both spring and fall.

Acknowledgements

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knowledged. The willing cooperation of personnel of the U.S. Coast Guard's Omega Navigation Station throughout the study greatly facilitated the investigation.

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Avian Mortality at Man-Made Structures: An Annotated Bibliography by Michael Avery, Paul F. Springer, and Nancy S. Dailey, contains 853 entries directly concerned with bird losses at man-made structures, primarily taken from U.S. journals and periodicals; *American Birds* being the greatest source of citations (230). These were mostly contained in regional reports and contained number of individuals and species killed during spring and autumn migrations, or migration records obtained from kill incidents with otherwise few details. This is a publication of the Biological Services Program and is available from the office of the Superintendent of Documents, U.S. Government Printing Office.

WEATHER INFLUENCES ON NOCTURNAL BIRD MORTALITY AT A NORTH DAKOTA TOWER

MICHAEL AVERY, PAUL F. SPRINGER, AND J. FRANK CASSEL

Most studies of bird losses at towers have dealt with weather conditions in a general manner (e.g. Tordoff and Mengel 1956, Kemper 1959, Taylor and Anderson 1973) because losses usually were not monitored on a daily basis throughout the entire migration season. Thus, weather conditions prevailing on nights of large, spectacular kills have received the most attention. Such nights are usually characterized by overcast skies, often with precipitation, winds favorable for migration, and in the fall the passage of cold fronts (e.g. Brewer and Ellis 1958).

In the course of a study of bird migration and mortality at the U.S. Coast Guard's Omega Navigation Station, located approximately 3 km west of LaMoure, North Dakota in the James River Valley (Avery et al. 1975), it was apparent that while occasional large kills occurred on overcast nights, considerable losses took place throughout the migration seasons under non-overcast skies, particularly in the spring. Since mortality was monitored daily and accurate weather data were available from nearby, it was possible to analyze the losses with respect to cloud cover and wind conditions during 4 entire migration seasons.

METHODS

The 366-m Omega tower is supported by 3 sets of 5 guy wires (34.9–60.3 mm diameter) spaced 120° apart. The guy wires are attached at heights of 53, 109, 167, 228, and 293 m. The lower 2 guys are anchored 122 m from the tower, the next 2 at a distance of 213 m, and the last at 297 m. In addition, 16 evenly spaced transmitting cables (50.8 mm diam.) extend from the top of the tower to a circular perimeter road 732 m away.

Searches for tower casualties were made every morning at daybreak (except for 7 days) during the study periods: 30 March–4 June and 8 August–15 November 1972 and 2 April–2 June and 12 August–3 November 1973. Because the size of the tower site and the dense vegetation on it made it difficult to find all bird casualties, the area under the guy wires (approximately 168 ha) was divided into 4 concentric strata (Avery et al. 1975): A, 0–46 m (0.66 ha) from the tower; B, 47–92 m (1.97 ha); C, 93–183 m (7.88 ha); and D, 184–732 m (157.61 ha). During the daily searches, stratum A was checked completely. The approximate areas searched in the other strata were: B—0.37 ha (18.8%), C—0.50 ha (6.3%), and D—1.51 ha (1.0%). The location and condition of each bird were recorded as it was collected, and only specimens judged to have died during the previous night were included in the analyses presented here, unless stated otherwise.

Because official weather data are not available from LaMoure, hourly weather reports were obtained from the Federal Aviation Administration Flight Service Station at Jamestown, 72 km north-northwest of LaMoure. A few of the records were discarded inadvertently by the station prior to analysis; thus, cloud cover and wind data are not available for these nights. Each of the 225 nights for which we have records of cloud cover was characterized as overcast or non-overcast. Four classes of cloud cover are recognized in the official weather reports—< 0.1 sky cover, 0.1 to < 0.6, 0.6 to 0.9, and > 0.9. These were assigned the numbers 0, 1, 2, and 3, respectively, and the 13 hourly figures from 1800–0600 CST were summed. The mean was calculated and a night was designated overcast if the mean was ≥ 2.5. All other nights were called non-overcast. This distinction is somewhat arbitrary and, conceivably, if different criteria were used, slightly different interpretations of the data would result. Wind direction and estimates of cloud cover made at the Omega tower corresponded well with the official weather reports from Jamestown.

The mean, nightly, surface wind direction was calculated from the hourly records; and the mean directions were grouped into four 90° sectors. Nocturnal bird migration in this region is primarily along a northwest-southeast axis (Richardson and Gunn 1971, Avery et al. 1976), and in this paper winds are referred to as favorable if from the 106°–195° quadrant on spring nights and 286°–015° on fall nights.

Losses in the 3 most frequently killed families, Rallidae, Parulidae, and Fringillidae, were examined during their respective periods of peak migration as indicated by field surveys conducted several times weekly near the tower site. Only the losses on nights within each of these peak migration periods were used in these analyses. Chi-square goodness-of-fit tests were used to determine if, within each family, the losses occurring during the entire peak periods in each cloud-wind category were in the same proportions as the number of nights in those categories. The G-test (Sokal and Rohlf 1969) was used to ascertain independence between cloud cover and distance of kill from the tower (Table 4) and between cloud cover and season (Table 5). Prior to analysis, the data used in Tables 4 and 5 were corrected for differences in the area searched in each stratum. In all tests $p \leq 0.05$ was accepted as statistically significant.

RESULTS AND DISCUSSION

The 5, largest, single-night kills and the accompanying weather conditions are listed in Table 1. All occurred under an overcast sky with the exception of the night of 14–15 May 1972 which was moonless and clear. Weather data revealed no conditions of overcast or poor visibility anywhere in the region that night. The behavior of birds at the tower during the kills on overcast nights was generally similar to that described by previous authors (e.g. Cochran and Graber 1958) and is treated in more detail in another paper (Avery et al. 1976).

Although the largest collections of dead and injured birds were made following overcast nights, mortality occurred consistently on clear nights as well. Table 2 shows that during spring migration the percent of losses of rails and fringillids occurring on overcast nights was about the same as the rate of occurrence of those nights; however, spring mortality in warblers and fall mortality among all 3 families occurred on overcast nights in greater-than-expected percentages ($p \leq 0.05$).

During their peak periods of spring migration, rails and fringillids were

TABLE 1

THE 5 LARGEST SINGLE-NIGHT LOSSES AT THE OMEGA TOWER IN 1972 AND 1973

Night of kill	Birds found	Weather conditions during night
25–26 Sept. 1973	69	overcast, light rain, light ENE wind
4–5 Oct. 1972	48	overcast, NE wind 5–15 k
14–15 May 1972	27	clear, light S wind
10–11 May 1972	25	overcast, drizzle, light S wind
21–22 Aug. 1972	23	overcast, NW wind 10–15 k

killed in significantly greater numbers on non-overcast nights with southeasterly winds than on nights with other conditions (Table 3). Conversely, warblers were killed in significantly greater numbers on overcast nights. In the fall, losses at night during peak migration periods under the various conditions of cloud cover and wind direction were distributed in about the same frequency as the occurrence of nights with these conditions except for warblers and fringillids which were killed in significantly greater numbers on overcast nights with northeasterly winds.

The high proportion of fall losses on overcast nights within 12 h after the passage of a cold front is consistent with other published reports (Brewer and Ellis 1958, Tordoff and Mengel 1956, Laskey 1960, Taylor and Anderson 1973). The fall losses presented in Tables 2 and 3 were due primarily to the few, large, single-night kills (Table 1), each of which was preceded by a cold front through the LaMoure area.

TABLE 2

PERCENT OF LOSSES OCCURRING ON OVERCAST NIGHTS AT THE OMEGA TOWER IN 1972 AND 1973

Family or group	Spring[1] (%)	Number of birds	Fall (%)	Number of birds
Rallidae	35	34	41*	22
Other non-passerines	36	11	50	10
Parulidae	64*	44	81*	135
Fringillidae	32	104	64*	100
Other passerines	48	57	70	46
Total	42	250	70	313
Percent of overcast nights	32		22	

[1] * Indicates statistical significance between % of loss and % of overcast nights.

TABLE 3

PERCENT LOSSES IN RELATION TO CLOUD COVER AND WIND DIRECTION AT THE OMEGA TOWER IN THE PEAK MIGRATION PERIODS IN 1972 AND 1973

Family	Cloud cover[1]	Surface wind quadrant[2] NW 286–015°	NE 016–105°	SE 106–195°	SW 196–285°	No. of birds and (nights)
Spring						
Rallidae	o	20(27)[3]	40(39)	40(23)	0(12)	5(26)
	n	29(42)	12(16)	53(24)*	6(18)	17(55)
Parulidae	o	32(15)	0(23)	59(54)*	9(8)	22(13)
	n	20(47)	0(14)	50(25)	30(14)	10(36)
Fringillidae	o	21(15)	21(35)	57(40)	0(10)	28(20)
	n	3(43)	16(18)	68(27)*	13(12)	62(49)
Fall						
Rallidae	o	33(38)	67(31)	0(13)	0(19)	3(16)
	n	11(24)	11(20)	33(26)	44(30)	9(66)
Parulidae	o	23(13)	70(50)*	3(13)	4(25)	69(8)
	n	37(23)	21(27)	16(17)	26(33)	19(30)
Fringillidae	o	2(24)	91(24)*	2(29)	6(24)	54(17)
	n	20(24)	5(10)	10(27)	65(39)	20(41)

[1] o = overcast, n = non-overcast.
[2] * Indicates statistical significance between % of loss and % of nights with indicated weather conditions.
[3] % of nights in each wind category are in parentheses.

Spring losses were not characterized by large kills but were smaller and more evenly distributed throughout the season. There was no direct association of spring losses with frontal movements; the bulk of the losses occurred on nights with favorable (i.e. southeasterly) winds. Ceilometer observations made at the tower revealed that the bulk of spring migration took place on nights with southeasterly winds.

The percent of losses of birds recovered within various distances of the tower varied with cloud cover (Table 4). In each family or group the percent killed in stratum A on overcast nights was similar to that on non-overcast nights. Among rails and other non-passerines, the losses on non-overcast nights were distributed approximately evenly among the 4 strata. Losses to passerines on non-overcast nights consistently exceeded those on overcast nights in strata C and D. In each family or group, losses on non-overcast nights in stratum D were 3 or 4 times those on overcast nights. Non-passerines suffered substantially greater losses in the outermost stratum than did passerines, particularly on non-overcast nights. Overall, losses on overcast nights were concentrated near the tower in strata A and B, whereas losses on non-overcast nights were more evenly distributed, 9% occurring at least 184 m from the tower. Within warblers, finches, and total birds, the distribution of kill by strata on overcast nights differed significantly from that on non-overcast nights.

TABLE 4

PERCENT OF LOSSES BY STRATUM AT THE OMEGA TOWER ON OVERCAST AND NON-OVERCAST NIGHTS IN THE 1972 AND 1973 MIGRATION SEASONS

Family or group[1]	Cloud cover[2]	Percent by stratum A	B	C	D	Number of birds
Rallidae	o	23	36	36	5	21
	n	22	28	28	22	35
Other non-passerines	o	43	21	29	7	9
	n	31	19	25	25	12
Parulidae*	o	44	43	13	1	137
	n	50	20	26	4	42
Fringillidae*	o	29	46	23	2	97
	n	30	35	28	8	107
Other passerines	o	34	38	27	2	59
	n	25	41	28	6	44
All birds*	o	36	42	20	2	323
	n	31	32	27	9	240

[1] * Indicates statistical significance between overcast and non-overcast nights.
[2] o = overcast, n = non-overcast.

Table 5 shows how the distance of kills from the tower varied with cloud cover and season. In both spring and fall, greater percentages of the seasonal losses were generally found in the 2 innermost strata under overcast conditions than under non-overcast. Conversely, in strata C and D, relatively more birds were found dead following non-overcast nights in both spring and fall than following overcast nights. When mortality between seasons is compared, spring losses were generally less than fall losses in strata A and B but exceeded the fall losses in strata C and D on both overcast and non-overcast nights. In both spring and fall, the differences in mortality between overcast and non-overcast nights within the strata were statistically significant and indicate that the distance of losses from the tower was influenced by cloud cover.

The differences in location of tower casualties in spring and fall is depicted in Fig. 1. This graph includes all of the tower casualties found in 1972 and 1973 and consists of raw data uncorrected for differences in areas searched. It shows that in each year the percent of fall losses exceeded those of spring within 92 m of the tower. Beyond 92 m the situation was reversed,

TABLE 5

PERCENT OF LOSSES BY STRATUM AT THE OMEGA TOWER ON OVERCAST AND NON-OVERCAST NIGHTS IN 1972 AND 1973

Season[1]	Cloud cover[2]	Percent by stratum A	B	C	D	Number of birds
Spring*	o	34	34	28	4	104
	n	26	32	30	12	146
Fall*	o	37	45	17	1	219
	n	40	31	23	6	94

[1] * Indicates statistical significance in % of losses by strata between overcast and non-overcast nights.
[2] o = overcast, n = non-overcast.

except for the 184–229 m interval in 1972. These results, although not statistically significant in 1973, show that, except for this one exception, larger spring losses consistently occurred at greater distances from the tower than did fall losses.

Cloud conditions seem to have a considerable effect on the manner in which bird mortality actually occurs at the Omega tower. From the results obtained it appears that most fall mortality takes place when large numbers of birds are aloft on overcast nights. Such nights are usually closely associated with the passage of a cold front. On overcast nights, migrants congregate around the tower (Avery et al. 1976) and are killed near the structure by colliding with it, the guy wires and transmitting cables, or other birds. On the other hand, spring migrants are apparently aloft when winds are favorable, regardless of cloud cover (Table 3), and thus much mortality occurs on non-overcast nights when migrants are not congregated at the tower. On such nights, migrants actually seem to avoid the structure (Avery et al. 1976). Consequently, in the spring, sizable losses occur on non-overcast nights far from the central structure through collisions with outlying guy wires and the transmitting cables.

The regular occurrence of substantial bird losses on non-overcast nights is perhaps peculiar to the Omega tower with its widespread system of cables. Losses do occur on non-overcast nights at other towers with less extensive cable arrays (e.g. Stoddard and Norris 1967), but apparently they are not as great as at the Omega tower. Birds deviating from their flight path to avoid most towers may remove themselves from the danger of the supporting guy wires. The 16 transmitting cables extending from the top of the Omega tower, however, pose additional problems; and birds avoiding the tower, and hence the innermost supporting guy wires, are still liable to collide with the outer transmitting cables.

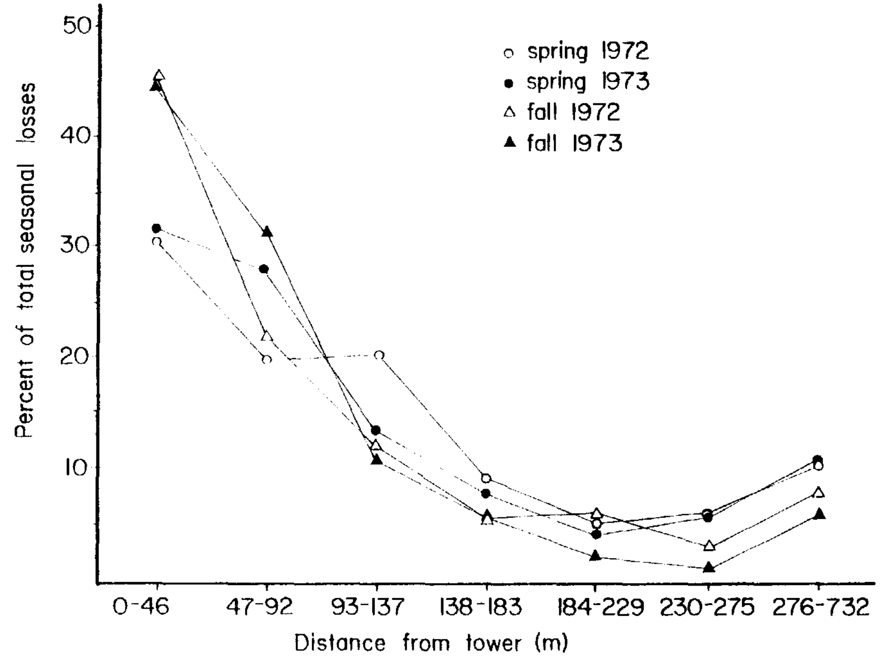

FIG. 1. The % of total seasonal losses collected at 46-m intervals from the Omega tower in 1972 and 1973.

Some of the differences in mortality among groups of migrants may be due to interspecific (or interfamilial) behavioral differences. For instance, at the Omega tower, warblers were prone to be killed close to the central structure (Table 4). Possibly warblers are influenced by red tower lights more so than are other groups, or perhaps warblers are less able to change direction to avoid inner guy wires than are other migrants. The sizable proportions of some kinds of non-passerines killed away from the tower, especially on non-overcast nights (Table 4), suggests behavioral differences that may be even more basic than family or group-level differences.

Overing (1936, 1937) also noted differences in the responses of various passerines to tall, lighted structures. On 20 October 1935, hundreds of Field Sparrows, *Spizella pusilla*, perched on benches at the base of the lighted Washington Monument; "None of these sparrows struck the monument that night, nor did they seem confused by the lights nor fly against the shaft, as the vireos and warblers were doing." The following fall, there was a similar occurrence. Of the 523 birds collected by Overing in the falls of 1935 and 1936, only 7 were fringillids. Further differences are suggested by Stoddard and Norris (1967) who noticed that during nights of heavy rainfall, fringillids tended to persist in their migratory flight while warblers, vireos, and thrushes sought ground cover.

No experimental evidence exists detailing differences among various taxa of nocturnal migrants in their response to tall, lighted structures. This area warrants more attention because conceivably such an investigation could lead to methods whereby losses of some species at towers can be reduced.

SUMMARY

An examination of the cloud cover and wind conditions that accompanied bird losses at a 366-m tower in southeastern North Dakota revealed that most fall losses occurred under overcast skies associated with the passage of cold fronts. In the spring, 58% of the mortality took place on non-overcast nights, generally with southeasterly winds. Rails were killed in relatively equal proportions on overcast and non-overcast nights in both spring and fall. Warblers were killed in significantly greater numbers on overcast nights in both seasons, as were fringillids in the fall. Losses on non-overcast nights tended to be distributed farther from the tower than were those on overcast nights. Fall losses were concentrated closer to the tower than were spring losses because fall losses occurred mostly under overcast skies as migrants milled about the tower. Spring losses seemed to occur primarily on non-overcast nights through collisions with outlying guy wires and the transmitting cables. Behavioral differences among species or families of migrants may be involved in migrant mortality at towers.

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